OPERATING INSTRUCTIONS

for

THE MEDIUM POWER TEST SET

MODEL KP-1

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SECTION 1

GENERAL

1-1. GENERAL DESCRIPTION

The Baird-Atomic Medium Power Test Set, Model KP-1, is a laboratory measuring instrument, designed to obtain small signal and dc parameter data for most medium power transistors. The 'h' or hybrid parameters may be measured in either the grounded base or grounded emitter configuration. Used with an external oscillator and vacuum-tube voltmeter, it is an effective tool in transistor evaluation.

A built-in power supply, operating from 115v ac line, supplies a wide range of bias conditions. Separate meters allow convenient and precise settings of voltage and current values. The front panel controls and meters permit all operation adjustments to be made easily and accurately. Both collector and emitter circuits are fused for instrument protection.

1-2. ELECTRICAL CHARACTERISTICS

The input voltage should be between 110-120 volts, 60 cycle ac. The current drain will not exceed 1.5 amperes.

a. DC BIAS

(1) Ranges Available

	Grounded Base	Grounded Emitter
Emitter Current (I_e)	1-300 ma	1-300 ma
Collector Current (I_c)	1-300 ma	1-300 ma
Base Current (I_b)		0-60 ma
Collector Voltage (V_c)	0-100 volts	0-100 volts

(2) Meter Scales

Current	10, 30, 100, 300 ma full scale ± 3%
Voltage	1, 3, 30, 100 v full scale ± 3%
I_{co}	50, 500 μa full scale ± 3%
	1, 5, ma full scale ± 3%

(3) Bias Supply Impedances

DC Source Impedances

Emitter or Base:	300 ohms to 10 K ohms
Collector:	300 ohms

AC Source Impedances

Emitter or Base:	50 K ohms
Collector:	100 ohms

b. FREQUENCY RANGE OF SMALL-SIGNAL MEASUREMENTS

100 cps to 200 KC for grounded base hybrids and β

NOTE: Since beta cut-off, $f_{\beta o}$, can be measured to 200 KC, alpha cut-off, $f_{\alpha o}$, can usually be computed to over 1 mc, using the approximate relation:

$$f_{\alpha o} = \frac{f_{\beta o}}{1-\alpha}$$

c. COEFFICIENTS MEASURED DIRECTLY

HYBRID - Grounded Base . . . h_{11}, h_{12}, h_{21}, h_{22}, $1 + h_{21}$
HYBRID - Grounded Emitter . h_{11}, h_{12}, h_{21}, h_{22}, $1 + h_{21}$
CURRENT GAIN - Grounded Base . . . . . α, $1-\alpha$
CURRENT GAIN - Grounded Emitter . . . . β
ALPHA CUT-OFF . . . . f_α
BETA CUT-OFF . . . . f_β
COLLECTOR CAPACITANCE . . . . C_c
COLLECTOR SATURATION CURRENT . . I_{co}
CHANNEL EFFECT VOLTAGE . . . . V_{ch}

Forward and Reverse Characteristics of the Transistor

d. PARAMETER RANGE AND ACCURACY

The following ranges and accuracies are actual figures obtained in our laboratory. The results are taken with an oscillator output impedance of 600 ohms. The accuracies quoted are exclusive of VTVM errors.

(1) GROUNDED BASE

Parameter	Measurable Range	Accuracy	Limitations
h_{11}	*10-1000 ohms	3% to 100 Kc	h_{11} < 1000 ohms
		3% to 200 Kc	h_{11} < 500 ohms
h_{21}	0.1-10	3% to 100 Kc	h_{11} < 1000 ohms
		3% to 200 Kc	h_{11} < 500 ohms
$1 + h_{21}$ x 1.0	0.1-1	3% to 100 Kc	h_{11} < 1000 ohms
		3% to 200 Kc	h_{11} < 500 ohms
$1 + h_{21}$ x 0.1	.01-0.1	5% to 75 Kc	h_{11} < 1000 ohms
		5% to 120 Kc	h_{11} < 500 ohms
h_{12}	.0001-1	3% to 100 Kc	r_b < 1000 ohms
		3% to 200 Kc	r_b < 500 ohms

* The low end of h_{11} may be extended by increasing the oscillator output by a factor of 10.

Parameter	Measurable Range	Accuracy	Limitations
h_{22} x 1	0.1 - 10 umhos	5% to 75 Kc 5% to 120 Kc	r_b < 1000 ohms r_b < 500 ohms
h_{22} x 10	1 - 100 umhos	3% to 100 Kc 3% to 200 Kc	r_b < 1000 ohms r_b < 500 ohms
h_{22} x 100	10 - 1000 umhos	3% to 100 Kc 3% to 200 Kc	r_b < 1000 ohms r_b < 500 ohms

(2) GROUNDED EMITTER

Parameter	Measurable Range	Accuracy	Limitations
h_{11}	*10 - 1000 ohms	3% to 100 Kc 3% to 200 Kc	h_{11} < 1000 ohms h_{11} < 500 ohms
h_{21}	1 - 1000	3% to 100 Kc 3% to 200 Kc	h_{11} < 1000 ohms h_{11} < 500 ohms
h_{21}	.0001 - 1	3% to 100 Kc 3% to 200 Kc	βr_e < 1000 ohms βr_e < 500 ohms
h_{22} x 1.0	0.1 - 10 umhos	5% to 75 Kc 5% to 150 Kc	βr_e < 1000 ohms βr_e < 500 ohms
h_{22} x 10	1 - 100 umhos	3% to 100 Kc 3% to 200 Kc	βr_e < 1000 ohms βr_e < 500 ohms
h_{22} x 100	10 - 1000 umhos	3% to 100 Kc 3% to 200 Kc	βr_e < 1000 ohms βr_e < 500 ohms

*The low end of h_{11} may be extended by increasing the oscillator output by a factor of 10.

1-3. ACCESSORY EQUIPMENT

a. REQUIRED

(1) Supplied

One Adaptor, Model HS for transistors with standard pin spacing

One (1) coaxial output cable

(2) Not Supplied

Oscillator

No load output: 10V

Output impedance: . . . . .600 ohms or less (higher values permissible but operation may be less convenient)

A. C. Vacuum-Tube Voltmeter

Since the VTVM is used only to read differences between input and output, a high precision is not required.

Sensitivity	.001 V full scale with other ranges in decades up to 10 V full scale
Input impedance . . .	greater than 1/2 megohm

b. OPTIONAL

Cathode Ray Oscilloscope

This instrument is useful for monitoring transistor output signal for distortion or noise in cases of unusual bias.

Adaptors

Adaptors to accomodate most transistor pin configurations are available from Baird-Atomic.

SECTION 2

OPERATION

The test set is calibrated before shipment. No preliminary adjustments or calibration checks are needed.

2-1. PRELIMINARY SETTINGS

a. FOR PROPER OPERATION, PERFORM THE FOLLOWING STEPS:

(1) Connect an oscillator (not supplied) to the OSC Terminal. The black terminal is grounded.

(2) Connect a vacuum tube voltmeter (not supplied) to the AC VTVM connector with the coaxial cable provided.

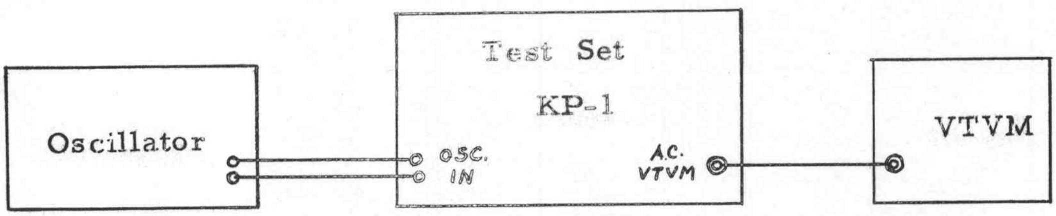

Figure 2-1. Connection Diagram

NOTE

Since the same VTVM is used both for setting input signal levels and for reading transistor coefficients, it does not have to be calibrated with absolute accuracy. If different scales are used for input and output, however, the final accuracy will be determined by the decade accuracy of the VTVM.

(3) Set the ON-OFF switch to the OFF position.

CAUTION

Transistors may be damaged if they are inserted or removed from the test set when this switch is ON.

(4) Plug appropriate adaptor into the octal socket and insert transistor into the adaptor.

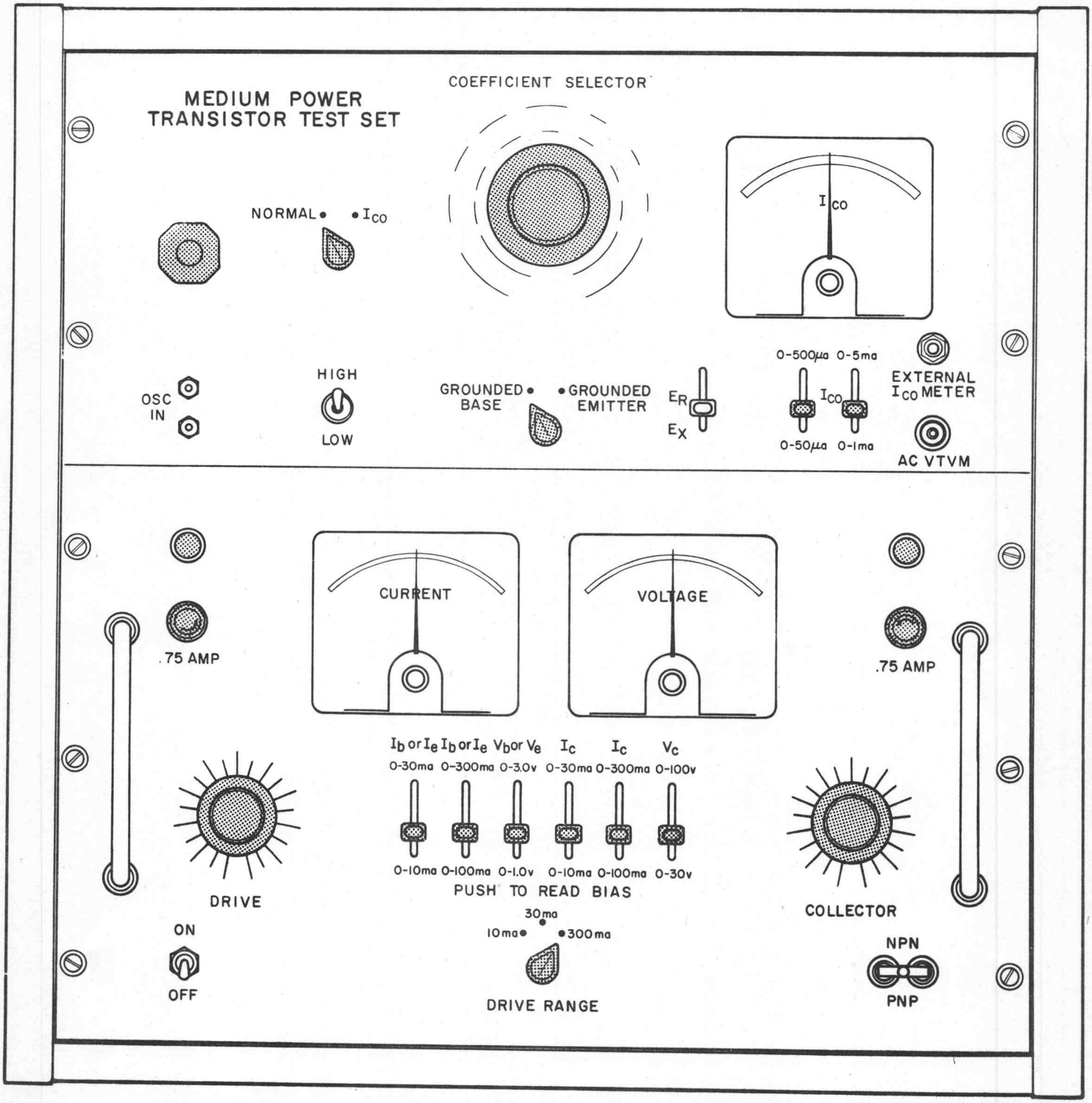

Figure 2-2, Operating Controls

TABLE 2-1 - PANEL CONTROLS AND SCALES

NAME	PRINCIPAL FUNCTION	SYMBOL
ON/OFF	In ON position, biases are applied to transistor, even if meter is not indicating, and pilot light glows. In OFF position, biases are removed from transistor socket.	S1 A, B, C,
NPN/PNP	Reverses polarity of bias for each transistor type. The collector polarity may be reversed to obtain the low voltage characteristics of the transistor in the reverse direction.	S2 A, B, C, D
h_b GROUNDED BASE-h_e GROUNDED EMITTER	Switches transistor configuration to either grounded base or grounded emitter.	S1 0, A, B, C, D
NORMAL/I_{co}	In NORMAL position, biases are applied as indicated by the associated switch settings. In I_{co} position, voltage is applied to the collector while the emitter circuit is open.	S11
HIGH/LOW	In LOW position, voltage from oscillator is reduced to permit finer control in setting the reference voltage, E_R. In HIGH position, voltage from oscillator is normal.	S5
VOLTAGE CURRENT and I_{co} meters	VOLTAGE meter indicates DC bias voltage and polarity when proper lever is pushed. CURRENT meter indicates DC bias current and polarity when proper lever switch is pushed. I_{co} meter indicates I_{co} in conjunction with NORMAL/I_{co} switch when proper lever switch is pushed.	M1, M2, M3
DRIVE RANGE	Limits or increases range of emitter current (I_e) indicated on the CURRENT meter.	S3
DRIVE	Sets emitter current to desired value in conjunction with lever switches and DRIVE RANGE switch.	T4

TABLE 2-1 - PANEL CONTROLS AND SCALES (cont.)

NAME	PRINCIPAL FUNCTION	SYMBOL
COLLECTOR	Sets collector voltage (V_c) to desired value in conjunction with lever switches.	T 2
PUSH TO READ BIAS	Six spring-return lever switches insert the CURRENT and VOLTAGE meters into the transistor circuit and, in conjunction with the DRIVE RANGE switch, select the meter range. In the center or neutral position the meters are out of the transistor circuit but the biases are applied. When a key is depressed the appropriate meter is inserted in the transistor circuit, and the existing bias is indicated on the meter. With the key depressed, the bias may be varied by adjusting the DRIVE or COLLECTOR knobs. NOTE I_e is the DC emitter current in the grounded base configuration. I_b is the DC base current in the grounded base configuration. V_e is the DC emitter to base voltage in the grounded base configuration. V_b is the DC base to emitter voltage in the grounded emitter configuration. I_c is the DC collector current. V_c is the DC collector voltage.	S4, A-E
COEFFICIENT SELECTOR	Selects the coefficient to be measured in conjunction with the GROUNDED EMITTER-GROUNDED BASE switch. the GE--GB switch adds, in effect, the subscript e or b to the indicated h parameters. Therefore two complete series of h coefficients can be selected. Coefficients not marked on the panel are obtained by setting COEFFICIENT SELECTOR to a corresponding parameter. The outer ring around the selector indicates the factor by which the final VTVM reading should be multiplied.	S7, A-F

TABLE 2-1 - PANEL CONTROLS AND SCALES (cont.)

NAME	PRINCIPAL FUNCTION	SYMBOL
E_R/E_X	In the center or E_R position the oscillator signal level can be adjusted to obtain the desired reference voltage. (Except when transistors exhibit distortion or noise, this value is 1 millivolt). In the E_X position the numerical value of the coefficient can be read on the VTVM.	S6
EXTERNAL I_{co} meter	Through this jack an external meter can be inserted into the I_{co} measuring circuit for a more accurate reading when I_{co} is below 2 μa.	J4
OSC IN	The external oscillator is connected to these terminals. The black terminal is grounded.	J1, J2
AC VTVM	The external VTVM is connected here.	J3

(5) Set NPN-PNP switch to the required position.

NOTE

Be certain that the bar link on the NPN-PNP switch throws both toggle switches.

(6) Set GROUNDED EMITTER-GROUNDED BASE switch to the proper position.

(7) Turn ON-OFF switch to the ON position. Pilot lamp should light.

2-2. SETTING BIAS

a. GROUNDED BASE CONFIGURATION

(1) After making the preliminary settings as outlined in Sec. 2-1 above, set DRIVE RANGE knob to the desired value (10, 30, 300 ma).

(2) Press I_e lever on switch bank labeled PUSH TO READ BIAS to the proper range value and adjust DRIVE control knob until the desired emitter current (ma) is read on the CURRENT meter. Release I_e lever.

CAUTION

Do not press I_e lever switch to the 10 ma position unless it is known that the current will be less than 10 ma. Excessive current in this range may damage the CURRENT meter.

(3) Press V_c lever (in the same switch bank) to the proper range position and adjust COLLECTOR knob until the desired collector voltage is read on the VOLTAGE meter. Release V_c lever.

The biases are now set for the grounded base configuration. Emitter voltage may be observed by pressing the V_e lever.

b. GROUNDED EMITTER CONFIGURATION

(1) After making the preliminary settings as outlined in Sec. 'a', set DRIVE RANGE knob to the desired value (10, 30, 300 ma).

(2) Press V_c lever on switch bank labeled PUSH TO READ BIAS to the proper range position and adjust COLLECTOR knob until the desired collector voltage is read on the VOLTAGE meter. Release V_c lever.

(3) Press I_c lever (in the same switch bank) to the proper range value and adjust DRIVE control knob until the desired collector current is read on the CURRENT meter. Release I_c lever.

(4) Recheck and adjust collector voltage as in Step 2. The biases are now set for the grounded emitter configuration. Base current (I_b) and base voltage (V_b) may be observed by pressing the I_b and V_b levers.

2-3. MEASURING 'h' PARAMETERS

a. The 'hybrid' or 'h' parameters are defined as follows:

h_{11} - the input impedance with output short-circuited.
h_{12} - the voltage feedback ratio with input open-circuited.
h_{21} - the current amplification with output short-circuited.
h_{22} - the output admittance with input open-circuited.

(1) After making the preliminary settings and setting the bias for grounded base or grounded emitter configuration (as outlined in Sec. 2-2), set the COEFFICIENT SELECTOR to the desired parameter.

NOTE

When measuring Alpha or h_{22}, see Sec. 2-9 for special ranges.

(2) Set oscillator to the desired frequency.

(3) With the E_r-E_x switch in the E_r position, adjust the oscillator output so that the external VTVM reads 1 millivolt (See Sec. 2-8 for regulating E_r to correct for transistor distortion and noise).

NOTE

If it is difficult to obtain 1 millivolt reading on the VTVM because the oscillator output cannot be sufficiently reduced, turn the HIGH-LOW switch to the LOW position to obtain finer control.

(4) Set the E_r - E_x switch to the E_x position and read E_x in millivolts on the VTVM. If the VTVM indicator must be read on a scale other than the millivolt scale, the proper decimal correction must be made.

(5) Divide E_x by E_r.

(6) Multiply E_x by E_r by the appropriate figure on the outer ring of the COEFFICIENT SELECTOR dial and include the measuring unit, if any, (e.g., ohm, micromhos). This will be the value of the 'h' parameter that has been selected.

2-4. MEASURING COLLECTOR CAPACITANCE (C_c)

a. Collector capacitance (C_c) is the effective capacitance between collector and base of the transistor.

(1) After making the preliminary settings and setting the bias for grounded base configuration as outlined in Sec. 2-2, set the oscillator frequency to 159 KC.

(2) Set the COEFFICIENT SELECTOR dial to h_{22} x 10 position.

(3) With the E_r - E_x switch in the E_r position, adjust the oscillator output so that the external VTVM reads 1 millivolt (See Sec. 2-8 for regulating E_r to correct for transistor distortion and noise).

NOTE

If it is difficult to obtain 1 millivolt reading on the VTVM because the oscillator output cannot be sufficiently reduced, turn the HIGH-LOW switch to the LOW position to obtain finer control.

(4) Press E_r - E_x switch to the E_x position and read C_c on the VTVM. This measurement is in $\mu\mu$f x 10.

(5) Drop the frequency of the external oscillator to a low value (100 to 10,000 cycles). Press the E_r - E_x switch to the E_x position and read C_c on the VTVM. If the reading has dropped four times or more in value, the original capacitance measurement was accurate.

NOTE

The Baird-Atomic adaptors are especially designed for low capacitance. The stray capacitance between collector and base at the transistor socket is approximately 0.1 μμf.

2-5. MEASURING COLLECTOR SATURATION CURRENT (I_{co}) AND CHANNEL EFFECT VOLTAGE (V_{ch})

a. COLLECTOR SATURATION CURRENT (I_{co}) is the DC reverse current which flows between base and collector in the common base circuit for a given applied voltage V_c when the emitter is open-circuited.

(1) After making the preliminary settings as outlined in Sec. 2-1, turn the NORMAL-I_{co} position.

WARNING

Do not press the I_{co} lever when the NORMAL-I_{co} switch is in the NORMAL position, since this may seriously damage the I_{co} meter.

(2) Press the appropriate V_c lever on the switch bank labeled PUSH TO READ BIAS to the proper range value and adjust COLLECTOR knob until the desired collector voltage is indicated on the VOLTAGE meter. Release the V_c lever.

(3) Press I_{co} lever, starting at highest range value (5 ma) and going to a lower range value when it has been determined that I_{co} can be read safely on a lower range scale.

(4) Read the collector saturation current on the I_{co} meter. Then release I_{co} lever.

NOTE

If I_{co} is below 2 μa, an external microammeter or galvanometer may be plugged into the EXTERNAL I_{co} METER jack so that I_{co} can be read more accurately. A two-wire phone plug is used for the connection. Press the I_{co} lever switch to the lowest range value (50 μa). This removes all shunts from the internal circuit.

b. CHANNEL EFFECT VOLTAGE (V_{ch}) is the increase in potential, over the theoretical value, between emitter and base with the emitter open-circuited. This potential increase between emitter and base is due to a conduction path between collector and emitter.

(1) After measuring I_{co}, as outlined above in Sec. 2-5a, V_{ch} may be measured by pressing the appropriate V_c lever on the switch bank, PUSH TO READ BIAS, and reading V_{ch} in volts on the VOLTAGE meter.

2-6. MEASURING FREQUENCY CUT-OFF

a. ALPHA (α) is defined as the small signal current amplification (or gain) factor between the emitter (input) and the collector (output) in the common base circuit with the output terminals shorted.

b. BETA (β) is defined as the small signal current amplification (or gain) factor between the base (input) and the collector (output) in the common emitter circuit with the output terminals shorted.

c. The Cut-Off Frequency (f_o) is the upper frequency limit at which the gain is 3 db down from its low frequency value. The drop is due to the finite time required for a current carrier to move from one electrode to another.

d. The following procedure holds for $f_{\alpha o}$ or $f_{\beta o}$:

(1) Make the preliminary settings and set the bias as outlined in Sec. 2-2.

(2) Set the COEFFICIENT SELECTOR to h_{21} and measure this parameter as outlined in Sec. 2-3.

(3) Increase oscillator frequency until Alpha or Beta drops 3db or to 0.707 of maximum reading at low frequency.

(4) Read $f_{\alpha o}$ or $f_{\beta o}$ on the oscillator frequency dial.

2-7. POINT CONTACT TRANSISTORS

a. The parameters of point-contact transistors should be measured in the grounded base configuration and in the PNP position.

b. Biasing and measuring procedures are standard.

c. For point contact transistors, the sign of the input impedance parameter, h_{11b}, may be either positive or negative. When measuring this parameter determine the polarity by checking with an oscilloscope for reversal between the phases of E_x and E_r.

2-8. COMPENSATION FOR TRANSISTOR DISTORTION AND NOISE

The reference voltage E_r must be regulated when distortion and noise in the transistor affect the accuracy of the parameter measurements.

a. DISTORTION

Distortion results when the peak-to-peak signal swing in the collector circuit is allowed to exceed the DC bias voltage on the collector. With the great majority of transistors, the recommended reference voltage of 1 millivolt will not cause distortion. If the collector voltage is less than 3 volts, however, distortion may occur, and the reference voltage E_r must be reduced.

(1) Check for distortion by monitoring the VTVM with an oscilloscope. If distortion is seen, reduce E_r until the distortion is eliminated.

(2) Obtain an E_x reading with this corrected value of E_r. The correct parameter will be E_x/E_r, in units.

b. NOISE

If readings are inaccurate because of high noise level, the reference voltage E_r must be increased.

(1) To check for noise: turn off the signal and observe the VTVM.

(2) If no noise is present, the reading will drop 10 to 1. If the VTVM indication does not drop sufficiently, increase amplitude of oscillator signal until the desired drop is observed.

(3) Obtain an E_x reading with this larger value of E_r. The correct parameter value will be E_x/E_r, in units.

2-9. SPECIAL RANGES

a. ALPHA

Three coefficients are available for measuring Alpha, viz., h_{21}, $1 + h_{21}$, $1 + h_{21} \times 0.1$. To determine the correct coefficient to be chosen, first measure Alpha in the general h_{21} position. This measurement

will be accurate to $\pm$ 3% and will indicate the range of values in which Alpha falls. If Alpha is less than 0.90, remeasure it in the $1 + h_{21}$ position. If Alpha is greater than 0.90, remeasure it in the $1 + h_{21} \times 0.1$ position.

b. OUTPUT ADMITTANCE (h_{22})

There are three positions available on the COEFFICIENT SELECTOR for reading h_{22}; viz., 1 umho, 10 umho, and 100 umho. The procedure for measuring h_{22} is to start at the 1 umho position, which covers a range from 0.1 - 10 umhos. If the external VTVM reads full scale, switch to the 1 umho position. This position covers a range from 10 - 100 umhos. If the external VTVM still reads full scale, switch to the 100 umho position. This position covers a range from 100 - 1000 umhos.

c. REVERSE COLLECTOR CHARACTERISTICS

The reverse collector characteristics may be obtained by setting the biases for grounded base as outlined in regular operational procedure. Usually, however, the collector voltage is set to low value (approximately 5 volts) for these characteristics.

After proper biases have been set, push the collector section only of the PNP-NPN switch to the opposite position and read bias meters by depressing proper lever switch.

SECTION 3
THEORY OF OPERATION

3-1. BASIC THEORY

a. A transistor operating linearly under small signal conditions may be represented by a 4-terminal network element or 'black box'.

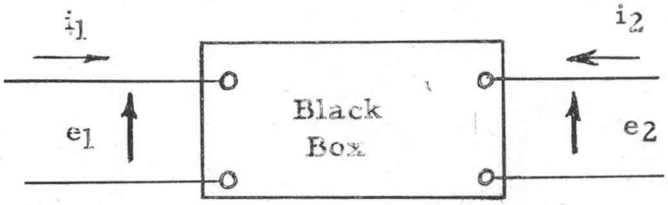

Figure 3-1.

The changes of voltage and current about a given operating point or set of dc biases may be represented in various ways by using open or short-circuited impedance or admittance parameters. From the point of view of measurability, a set of parameters involving a combination of both open-circuited and short-circuited conditions, called 'hybrid' parameters, has been found useful in junction transistor analysis. The hybrids are defined as the coefficients in the following equations for the 'black box':

$$e_1 = h_{11}i_1 + h_{12}e_2$$

$$i_2 = h_{21}i_1 + h_{22}e_2$$

By successively setting e_2 and i_1 to zero, (that is, an ac short-circuited output and an ac open-circuited input respectively) in each equation, we have:

$$h_{11} = \left.\frac{e_1}{i_1}\right|_{e_2 = 0}$$ = input impedance with output short-circuited.

$$h_{12} = \left.\frac{e_1}{e_2}\right|_{i_1 = 0}$$ = voltage feedback ratio with input open-circuited.

$$h_{21} = \left.\frac{i_2}{i_1}\right|_{e_2 = 0}$$ = current amplification with output short-circuited.

$$h_{22} = \left.\frac{i_2}{e_2}\right|_{i_1 = 0}$$ = output admittance with input open-circuited.

The coefficient testing circuits of the B-A Transistor Test Set are based on the above parameter definitions.

b. An additional parameter, $1 + h_{21}$ (or $1 - \alpha$) has been added since it appears frequently in equivalent circuit computations and increases the accuracy when determining h_{21}.

c. There are two complete sets of hybrid parameters. The h - parameters with the subscript 'b' denote the 'base' configuration, and those with the subscript 'e' denote the 'emitter' configuration.

3-2. APPLIED THEORY

a. SIMPLIFIED MEASURING CIRCUITS

The simplified measuring circuits are shown in Figure 3-2. Blocking condensers, dc bias supplies, and metering circuits have been omitted for simplicity. The circuits closely follow the definitions of the h - parameters given in 3-1, above. The circuits for measuring h_{12} and h_{22} are shown with a closed input circuit. For all practical purposes, however, the input is open; since the 100 K resistor in the emitter circuit presents a very high impedance compared to the input impedance of the transistor.

b. INPUT SIGNAL

For h_{11}, h_{21} and $1 + h_{21}$, the input signal is 10 micro-amperes. For h_{12} and h_{22}, the applied signal is 1 volt. The 100K/100 ohm voltage dividers allow setting of a 1 volt signal level using the .001 volt scale on the vacuum tube voltmeter. This minimizes the amount of decade switching between the E_R setting and the E_X measurement.

Simplified Measuring Circuits of the Transistor Test Set

/ mv

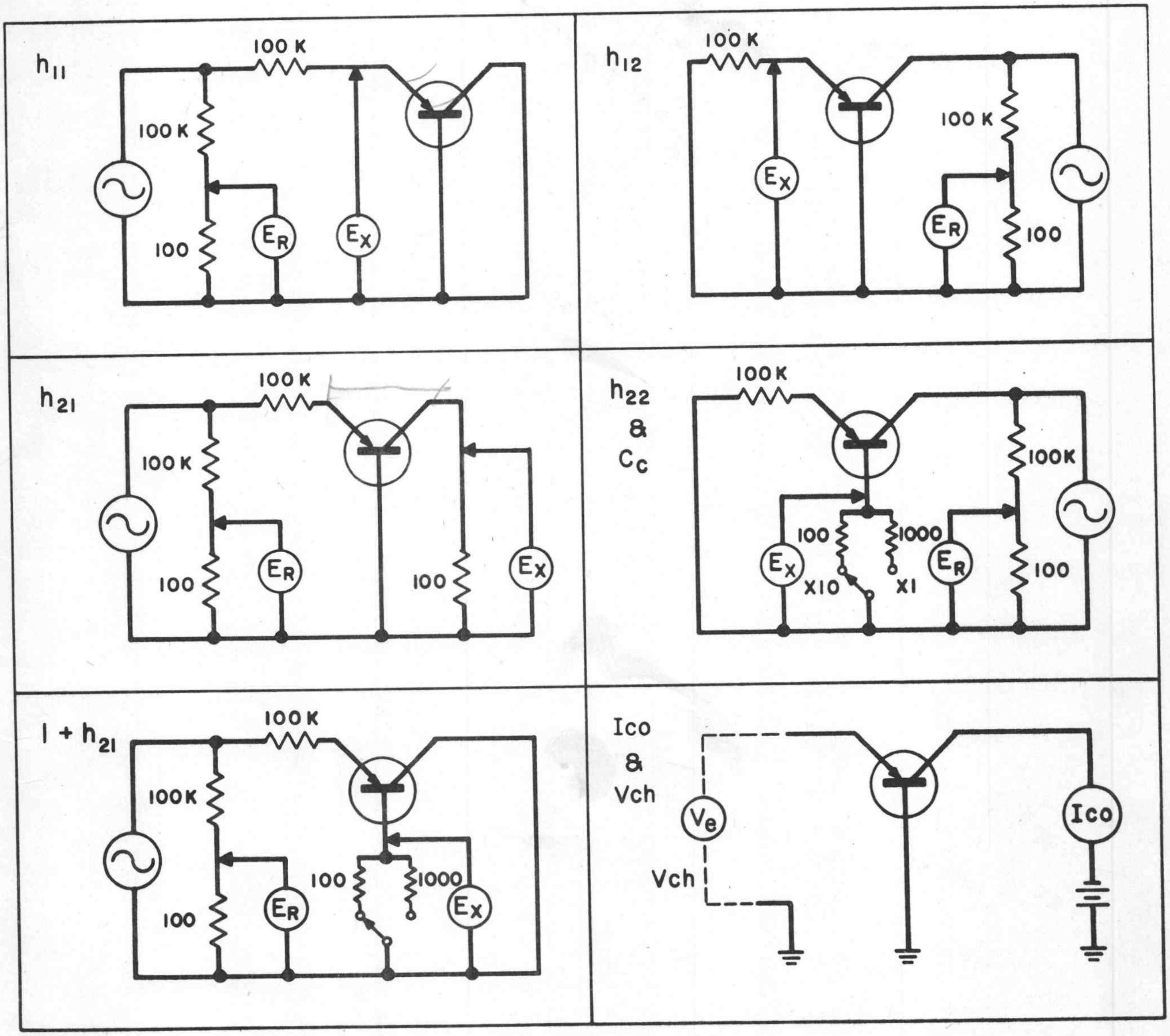

Figure 3-2, Simplified Measuring Circuits

c. COLLECTOR CAPACITANCE (C_c)

The effective capacitance between collector and base of the transistor is measured directly in the h_{22b} x 10 position, using f = 159 KC. The open-circuited admitance assuming C_c in parallel with r_{22} is

$$h_{22} = \frac{1}{r_{22}} \qquad i\omega C$$

At frequencies high enough such that

$$\omega C_c >> \frac{1}{r_{22}} \qquad\qquad h_{22} = \omega C_c$$

If f = 159 KC, $\omega = 10^6$, then h_{22} - $C_c \times 10^6 = C_c$ ($\mu\mu f$) or the magnitude of h_{22} as read will be equal to the capacitance. Since this reading must be multiplied by 10, the reading will be x 10 mmf. Neglecting $\frac{1}{r_{22}}$ will cause less than 5% error in C_c, provided r_{22} (in megohms) x C_c (in $\mu\mu f$) is greater than 3.

d. THE I_{co} MEASUREMENT

I_{co} is measured only in the h_{11}, h_{21} or h_{12} positions on the COEFFICIENT SELECTOR because the base is connected directly to ground in these positions, as shown in Figure 3-2.

3-3. FUNCTION OF COMPONENTS (See Figure 4-1 Schematic)

a. INPUT TO POWER SUPPLIES

The 115V AC line voltage is connected through the power switch and fuses to two variacs. One variac T2, marked 'COLLECTOR', controls the input to the primary of the collector power supply transformer. The other variac T4, marked 'DRIVE', controls the input to the primary of the power supply transformer for the emitter or base circuit, depending on which electrode is to be biased.

b. POWER SUPPLIES

The collector power supply and the emitter-base power supply are similiar in design and function. The power supply transformer is a 1:2 step-up transformer. The AC voltage across the transformer secondary is rectified by a silicon diode bridge network and filtered

through a two-section choke input filter to the NPN-PNP switch. The position of this switch determines the dc polarity for the collector and emitter-base circuits. These power supplies are capable of delivering 100V dc at 300 ma.

c. COLLECTOR CIRCUIT

The high side of the collector power supply is connected through a choke (L4) and the I_{co} meter circuit to the collector electrode of the transistor. The function of choke L4 is to isolate the collector power supply from the ac signal. When an I_{co} range switch is pressed, the I_{co} meter is connected directly into the collector circuit. The I_{co}-Normal switch when in the I_{co} position opens the emitter circuit for reading collector saturation current.

The low side of the collector power supply is connected through the CURRENT meter circuit to ground. When the I_c switches are pressed, the meter is connected into the collector circuit.

d. EMITTER - BASE CIRCUIT

When the GROUNDED EMITTER - GROUNDED BASE switch is in the GND EMITTER position, the high side of the emitter-base power supply is connected directly to the DRIVE RANGE switch which selects 10, 30, or 300 ma for the maximum emitter current. When this switch is in the GND BASE position, the high side of the emitter-base power supply passes through a voltage divider to the DRIVE RANGE switch which now selects 2, 6, or 60 ma for the maximum base current. The range selector is connected through a choke (L7) and the GND EMITTER - GND BASE switch to the electrode that is to be biased. The function of choke L7 is to isolate the emitter-base supply from the ac signal. The position of the GND EMITTER - GND BASE switch determines which electrode will receive the dc bias from the power supply. The other electrode is connected to ground when the switch is in this position.

The low side of the emitter-base power supply is connected through the GND EMITTER - GND BASE and the CURRENT meter circuit to ground. When the I_c-I_b switches are pressed, the current meter is connected into the circuit of the biased electrode.

e. VOLTMETER CIRCUIT

The voltmeter is connected across the high side of the collector or emitter-base circuits to the common electrode through a suitable range of resistors by pressing the V_c or V_b switches.

f. COEFFICIENT SELECTOR SWITCH

(1) Oscillator

The output of the oscillator is connected through J_1 and J_2 to a voltage divider (R_{16} and R_{17}), which permits voltage range selection. If the HIGH-LOW switch is in the HIGH position, the ac signal voltage drop is taken across the combination of R_{16} and R_{17}. If the HIGH-LOW switch is in the LOW position, the ac signal voltage drop is taken across R_{16} only. The ungrounded side of the ac signal is connected through the HIGH-LOW switch to wafer A of the COEFFICIENT SELECTOR switch.

(2) Wafer A

The function of wafer A in the Coefficient Selector switch is to connect the ungrounded side of the ac signal to the proper transistor electrode. In position 1, 2, 3, and 4 the ac signal is connected through C_5 and R_{23} to the GND EMITTER-GND BASE switch. The switch position determines which electrode will receive the ac signal input. The function of C_5 is to isolate the oscillator from the DC bias on the Emitter or base. The function of R_{23} is to supply a source of constant current. In positions 5, 6, 7, and 8 of wafer A, the ungrounded side of the ac signal is connected through capactor C_6 to the collector electrode of the transistor. The function of this capacitor is to isolate the oscillator from the DC collector voltage.

(3) Wafer B

The function of wafer B in the Coefficient Selector switch is to make the proper connection for the emitter or base, depending on which electrode is biased. In positions 1, 2, 3, and 4 of wafer B, a voltage divider, consisting of R_{24} and R_{25} is to provide an accurate means of measuring the ac signal reference voltage across the emitter to base circuit. In positions 5, 6, 7, and 8 of wafer B, the emitter or base is grounded through R_{23} and C_5.

(4) Wafer C

The function of wafer C of the Coefficient Selector switch is to make the proper connection for the collector of the transistor . In positions 1, 3, and 4, the collector at ac grounded; (in positions 2, it is grounded through R_{20}). In positions 5, 6, 7, and 8, a

voltage divider consisting of R_{21} and R_{22} is connected across the ac signal reference voltage on the collector side of the transistor. R_{21} and R_{22} are used to provide an accurate means of measuring the ac signal reference voltage applied to the collector circuit.

(5) Wafer D

The function of wafer D in the Coefficient Selector switch is to make the proper connection for the unbiased electrode, either emitter or base, depending upon which is grounded by the GND EMITTER-GND BASE switch. In positions 1, 2, and 5, the unbiased electrode is connected directly to ground. In positions 3 and 7, it is grounded through R_{20}; in positions 4 and 6, it is grounded through R_{17}; and in position 8, it is grounded through R_{20}.

(6) Wafer E

The function of wafer E of the Coefficient Selector switch is to connect the external VTVM to the proper circuit terminals where the desired parameter will be measured (when E_R-E_X position). In positions 1 and 5, the VTVM reads the voltage between emitter and base. In positions 2, 3, and 7, the VTVM reads the voltage drop across R_{20}; in positions 4 and 6, it reads the voltage drop across R_{19}; and in position 8, it reads the voltage drop across R_{18}.

(7) Wafer F

The function of wafer F in the Coefficient Selector switch is to connect the external VTVM across an accurately calibrated resistor so that the ac reference signal may be read (when the E_R-E_X position). In positions 1, 2, 3, and 4, the VTVM reads the ac signal reference voltage across R_{25} of the voltage divider in the emitter to base circuit. In positions 5, 6, 7 and 8, the VTVM reads the ac signal reference voltage across R_{22} of the voltage divider in the collector circuit.

SECTION 4

MAINTENANCE

4-1. GENERAL

Since the basic measuring circuit consists primarily of switches, meters and passive components, the most probable failures will be those associated with normal friction and wear. The most common source of trouble will be dirty switch contacts. Good housekeeping provides the best insurance against this type of failure.

4-2. PREVENTATIVE MAINTENANCE

With all electrical equipment, inspection and cleaning before trouble occurs often prevents malfunction. The following checks are recommended to insure long life and satisfactory operation.

a. EXTERNAL

(1) Check general condition of instrument.

(2) Clean dirt and moisture from front panels and all connectors.

(3) Check seating of accessible plug-out items: fuses, sockets, connectors, etc.

(4) Inspect controls for looseness, misalignment and positive action.

(5) Inspect cords for cuts, breaks, fraying, kinks or strain.

b. INTERNAL

(1) Inspect the seating of all lamps and fuses.

(2) Remove dirt, moisture and foreign matter from chassis.

(3) Inspect all joints and connectors for tightness and positive contact.

(4) Inspect fixed capacitors for bulges and discoloration.

(5) Inspect resistors, chokes and transformers for blistering and discoloration.

4-3. VISUAL INSPECTION

a. Failure of this equipment to operate may be caused by one of the following faults.

(1) Plug-in units not secure

(2) Burned-out fuse

(3) Defective transformer

(4) Resistors burned out by capacitor failure

(5) Loose connections

b. When failure is encountered and the cause is not immediately apparent, check as many of the above items as practicable before starting a detailed examination of the components. LOOK FOR THE SIMPLE TROUBLES FIRST. The troubleshooting chart (Table 4-1) should be of some aid in attempting to localize the fault.

TROUBLESHOOTING CHART

SYMPTOM	PROBABLE CAUSE	CORRECTION
Collector pilot light goes out and fuse is blown.	Trouble in collector power supply.	Check diodes and filter capacitors (CR1, C1, and C2). Replace fuse.
Emitter-Base pilot light goes out and fuse is blown.	Trouble in emitter-base power supply.	Check diodes and filter capacitors (CR2, C3, and C4). Replace fuse.
Pilot lights go out and fuses aren't blown.	Panel to power supply plug disconnected.	Connect plug.
No collector voltage on transistor with collector pilot light lit.	Broken connection or defective component in collector power supply.	With a VTVM, trace collector supply voltage from choke L4.
No emitter or base current on transistor with emitter-base pilot light lit.	Broken connection or defective component in emitter-base power supply.	With a VTVM, trace emitter supply from choke L7. Check switch S10
No voltage on VTVM when E_X-E_R switch in E_R position.	Broken connection or defective panel-mounted component.	Check switch S5, S6, and trace voltage through coefficient selector switch.
No reading on meter (s).	Broken connection or dirty switch contacts.	Check associated bias switches. (See Schematic)

TABLE 4-1

TROUBLESHOOTING CHART

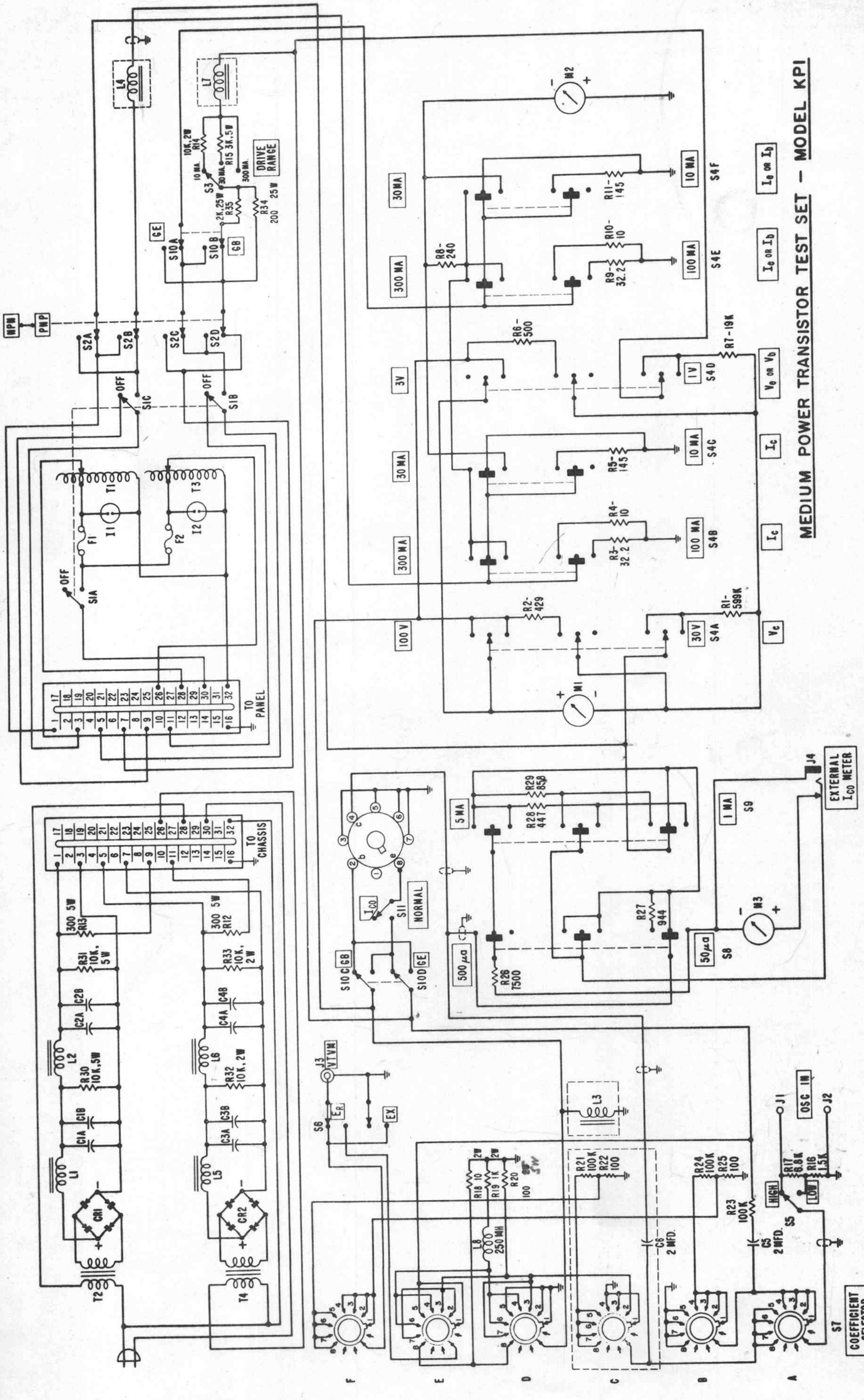

Figure 4-1, Schematic

SECTION 5

REPLACEMENT PARTS LIST

Reference Symbol	Name	and Description	Special Information
	Adaptor - HS1		B-A
C1, C2, C3, C4	Capacitor, Electrolytic	2 x 150 mfd, at 250V	Aerovox AFHS-2-30
C5, C6	Capacitor	2 mfd, 200V, mylar	Goodall 620M
CR1, CR2, CR3, CR4, CR5, CR6, CR7, CR8	Crystal Rectifier	Silicon	Sarkes Tarzain M-500
F1, F2	Fuse	0.75 amp	Buss. 3AG
I1, I2	Lamp, NE51	Neon	
J3	Connector, Receptacle		Amphenol 83-1R
J4	Phone Jack		Switchcraft 12A
J5	Connector, Socket		Amphenol 26-4200-32S
J6	Connector, Plug		Amphenol 26-4100-32P
L1, L2, L5, L6	Choke		UTC S-34
L4	Choke, Special		CKP1-4608-2
L3, L7	Choke, Special		CKP1-4608-1
M1	Meter, Voltage		AW-102-10
M2	Meter, Current		BW-102-11
M3	Meter, Ico		BW-1 2-9
R1	Resistor	599K, 1/2W, 1%	Allies APST 1/2

REPLACEMENT PARTS LIST

Sheet 2

Reference Symbol	Name and Description		Special Information
R2	Resistor	429 ohms, 1/2W, 1%	Allies APST 1/2
R3, R9	Resistor	32.2 ohms, 1/2W, 1%	Allies APST 1/2
R4, R10	Resistor	10 ohms, 1/2W, 1%	Allies APST 1
R5	Resistor	145 ohms, 1/2W, 1%	Allies APST 1/2
R6	Resistor	500 ohms, 1/2W, 1%	Allies APST 1/2
R7	Resistor	19K, 1/2W, 1%	Allies APST 1/2
R8	Resistor	240 ohms, 1/2W, 1%	Allies APST 1/2
R12, R13	Resistor	300 ohms, 5W, 10%	Ohmite
R14	Resistor	10K, 2W, 10%	Allen Bradley
R15	Resistor	3K, 5W, 10%	Allen Bradley
R16	Resistor	1.5K, 1/2W, 10%	Allen Bradley
R17	Resistor	6.8K, 1/2W, 10%	Allen Bradley
R18	Resistor	10 ohms, 2W, 1%	AlliesAPT-2
R19	Resistor	1K, 2W, 1%	Allies APT-2
R20	Resistor	100 ohms, 5W, 1%	Allies APT-5
R21, R23, R24	Resistor	100K, 1/2W, 1%	Allies APT 1/2
R22, R25	Resistor	100 ohms, 1/2W, 1%	Allies APT 1/2
R26	Resistor	7.5K, 1/2W, 1%	Allies APST 1/2
R27	Resistor	944 ohms, 1/2W, 1%	Allies APST 1/2
R28	Resistor	447 ohms, 1/2W, 1%	Allies APST 1/2
R29	Resistor	85.8 ohms, 1/2W, 1%	Allies APST 1/2

REPLACEMENT PARTS LIST

Sheet 3

Reference Symbol	Name and	Description	Special Information
R30, R31	Resistor	10K, 5W, 10%	Ohmite
R32, R33	Resistor	10K, 2W, 10%	Ohmite
R34	Resistor	200 ohms, 25W, 10%	Ohmite
R35	Resistor	2K, 25W, 10%	Ohmite
S1	Switch, Toggle	4 Pole, Double Throw	C.H. 766K4
S2	Switch, Toggle	DPDT, Ball Handle	I.C.A. 1364
S3	Switch, Rotary	1 Pole, 3 Position	Grigsby-Allison 12888-4MLR-1
S4	Switch, Lever	6 Sec. 3 Pole, 3 Position	Grigsby-Allison 11975-6100LR-6
S5	Switch, Toggle	SPDT	C.H. 8282
S6	Switch, Lever	2 Pole (N.S.), 3 Position	Centralab. 1467
S7	Switch, Rotary	Deluxe Index Assembly	Centralab. JD
		Phenolic Section (N.S.)	Centralab. BD
		Phenolic Section (S)	Centralab. P-148
S8, S9	Switch, Lever	3 Pole(S), 3 Position	Centralab. PA-220-122
S10	Switch, Rotary	4 Pole(N.S.) 2 Position	Grigsby-Allison 14060-4MLR-1
S11	Switch, Rotary	1 Pole(N.S.) 2 Position	Grigsby-Allison 12890-4MLR-1
T1, T3	Auto Transformer, Var.		Sup. Elec., Type 10
T2, T4	Transformer		Precision Elec. BA-9MA